ONE-PIECE END CAP FOR A MUFFLER AND METHOD OF FORMING SAME

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] This invention relates, in general, to mufflers for internal combustion engines, and more particularly to muffler end caps and methods for forming the same.

Description of Related Art

[0002] Mufflers for internal combustion engines typically have a main body, often formed by a tubular casing, that is enclosed by a pair of end cap assemblies. An inlet pipe piece is conventionally welded to a forward end wall piece to form the forward end cap assembly, while an outlet pipe piece is conventionally welded to a rearward end wall piece to form the rearward end cap assembly.

[0003] Conventional end cap assemblies (e.g., end cap assembly 20, as shown in FIG. 1) are generally preassembled, that is, the inlet and outlet pipes (e.g., pipe 21) are attached to a respective end wall (e.g., end wall 22) before the end cap assemblies are welded or otherwise secured to the main body of a muffler. Typically, the end wall is stamped or punched from a flat sheet of steel and formed with an inlet or outlet opening or port 23 extending therethrough. The end cap often will have a flared frustoconical attachment flange (e.g., flange 24) surrounding and defining opening 23 that will correspond with a respective inlet or outlet pipe 21. Typically, a short piece of tubing is rolled from another flat sheet of steel and is cut-to-length to form a respective inlet or outlet pipe 21, as shown in FIG. 2. One end of the pipe is then

flared (e.g., flared end 25) to mate with attachment flange 24 of end wall member 22. To finish the end cap assembly, flared end 25 of pipe 21 is then welded to attachment flange 24 of end wall 22.

[0004] An exemplar of a prior muffler utilizing a conventional end cap assembly is U.S. Patent No. 6,089,347 to Flugger, which patent discloses a muffler with an improved partition array. While such prior mufflers are very effective in attenuating sound and are quite durable, such mufflers, as well as other prior mufflers manufactured with conventional end caps, have certain disadvantages. For example, conventional end caps typically have rolled inlet and outlet pipes that include seams (e.g., seam 28). Such seams may split during manufacturing, for example, during the flaring process. Eliminating the use of seamed pipes would improve manufacturing efficiency and also reduce waste in producing mufflers.

[0005] Another disadvantage of prior mufflers which utilize conventional end cap assemblies is that such mufflers are subject to failure in the heat-affected zone of the weld that attaches the inlet and outlet pipes to the respective end walls. For example, through destructive testing of mufflers formed with conventional end caps conducted by Flowmaster, Inc., the assignee of the present invention, it has been determined that a majority of muffler failures occur at the pipe-to-wall weld (e.g., weld 29) of conventional end cap assemblies 20.

[0006] What is needed is a new and improved muffler end cap which overcomes the above and other disadvantages of conventional muffler end caps.

BRIEF SUMMARY OF THE INVENTION

[0007] In summary, one aspect of the present invention is directed to an end cap for an internal combustion engine muffler having a muffler casing defining a muffler chamber. The end cap includes an end wall having an aperture, a mounting structure dimensioned and configured for securing the end wall to an end of the muffler casing, and a tubular member extending from the end wall adjacent to and surrounding the

aperture, the tubular member and the aperture defining an exhaust port for the muffler chamber, the tubular member being monolithically formed with the end wall.

[0008] In one embodiment, the end wall includes a peripheral shoulder extending along at least a portion of a periphery of the end wall. The peripheral shoulder may define an stepped land and a substantially flat outer surface.

[0009] The aperture and the tubular member may be centrally located on the end wall. Alternatively, the aperture and the tubular member may be asymmetrically located on the end wall.

[0010] In one embodiment, the end cap includes a filleted portion at the intersection of the end wall and the tubular member, the filleted portion being monolithically formed with the end wall and the tubular member.

[0011] Another aspect of the present invention is directed to a method of forming a muffler end cap including the steps of providing a substantially flat metal blank, and drawing a tubular member having a bore and an end wall from the blank thereby monolithically forming the tubular member and the end wall from the blank.

[0012] Yet another aspect of the present invention is directed to a muffler for an internal combustion engine including a main body including a casing defining a muffler chamber and having a forward end and a rearward end, a forward end cap including a forward end wall having an inlet aperture, a forward mounting structure secured to the forward end of the casing, and an inlet tube extending forwardly from the forward end wall forming an inlet to the muffler chamber, the forward end wall and the inlet tube being monolithically formed, and a rearward end cap including a rearward end wall having an outlet aperture, a rearward mounting structure secured to the rearward end of the casing, and an outlet tube extending rearwardly from the rearward end wall forming an outlet from the muffler chamber, the rearward end wall and the outlet tube being monolithically formed.

[0013] In one embodiment, the casing includes an oblong tubular member defining the muffler chamber. The forward mounting structure may include a forward mounting flange extending around a periphery of the forward end wall welded to the forward end of the casing. Similarly, the rearward mounting structure may include a rearward mounting flange extending around a periphery of the rearward end and welded to the rearward end of the casing. At least one of the inlet and outlet tubes may be centrally located on at least one of the respective forward and rearward end walls. Alternatively, at least one of the inlet and outlet tubes may be asymetrically located on at least one of the respective forward and rearward end walls.

[0014] An object of the present invention is to provide a one-piece muffler end cap that does not require a pipe-to-wall weld.

[0015] Another object of the present invention is to provide a method for forming the above-mentioned one-piece muffler end cap.

[0016] Yet another object is to achieve one or more of the foregoing objects with a muffler that is inexpensive to manufacture and install.

[0017] The one-piece end cap for a muffler and method of the present invention has other features and advantages which will be apparent from or are set forth in more detail in the accompanying drawings, which are incorporated in and form a part of this specification, and the following Detailed Description of the Invention, which together serve to explain the principles of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] FIG. 1 is a side elevational view of a conventional prior art end cap assembly having a rolled inlet/outlet pipe welded to a stamped end wall.

[0019] FIG. 2 is an end elevational view of the rolled inlet/outlet pipe of FIG. 1.

[0020] FIG. 3 is an end elevational view of the stamped end wall of FIG. 1.

[0021] FIG. 4 is a perspective view of a muffler end cap constructed in accordance with the present invention.

[0022] FIG. 5 is an end elevational view of the muffler end cap of FIG. 4.

[0023] FIG. 6 is a side elevational view of the muffler end cap of FIG. 4.

[0024] FIG. 7 is a perspective view of another embodiment of the muffler end cap in accordance with the present invention.

[0025] FIG. 8 is an end elevational view of the muffler end cap of FIG. 7.

[0026] FIG. 9 is a side elevational view of the muffler end cap of FIG. 7.

[0027] FIG. 10 is a schematic cross-sectional view of a punch and die set configured for performing a first deep drawing operation in accordance with the present invention, together with an end cap as drawn thereby.

[0028] FIG. 11 is a schematic cross-sectional view of a punch and die set configured for performing a second deep drawing operation in accordance with the present invention, together with an end cap as drawn thereby.

[0029] FIG. 12 is a schematic cross-sectional view of a punch and die set configured for performing a third deep drawing operation in accordance with the present invention, together with an end cap as drawn thereby.

[0030] FIG. 13 is a schematic cross-sectional view of a punch and die set configured for performing a fourth drawing operation in accordance with the present invention, together with an end cap as drawn thereby.

[0031] FIG. 14 is a schematic cross-sectional view of a punch and die set configured for performing a stamping operation in accordance with the present invention, together with an end cap as formed thereby.

[0032] FIG. 15 is a schematic cross-sectional view of a punch and die set configured for performing a punching operation in accordance with the present invention, together with an end cap as formed thereby.

[0033] FIG. 16 is a schematic cross-sectional view of a punch and die set configured for performing an additional drawing operation in accordance with the present invention, together with an end cap as formed thereby.

DETAILED DESCRIPTION OF THE INVENTION

[0034] Reference will now be made in detail to the preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings. While the invention will be described in conjunction with the preferred embodiments, it will be understood that they are not intended to limit the invention to those embodiments. On the contrary, the invention is intended to cover alternatives, modifications and equivalents, which may be included within the spirit and scope of the invention as defined by the appended claims.

[0035] Turning now to the drawings, wherein like components are designated by like reference numerals throughout the various figures, attention is directed to FIG. 1 through FIG. 6 which illustrate a muffler 30 utilizing the one-piece or monolithically formed muffler end cap and inlet/outlet pipe of the present invention, which end cap is generally designated by the numeral 31. End cap 31 may be used in combination with an otherwise conventional muffler casing 32 to form muffler 30. For example, the one-piece muffler end cap of the present invention may be utilized in combination with any one of the mufflers disclosed by U.S. Patent Nos. 6,089,347, 5,444,197, 5,123,502, 4,809,812, and/or 4,574,914, the entire content of which patents is incorporated herein by this reference.

[0036] In the embodiment illustrated in FIG. 1, muffler casing 32 is a tubular member having an oblong transverse cross section, which casing generally defines an interior muffler chamber which will typically be provided with sound-attenuating partitions, secured in the casing in a well-known manner. One should appreciate that the muffler casing may be of various forms and shapes within the scope of the present invention. For example, the muffler casing may have a cylindrical or rectangular transverse cross section, or other suitable shape. One will also appreciate that the muffler casing may be formed of a single tubular member or formed of a plurality of members. For example, the muffler casing may be formed of longitudinally extending casing halves which are joined together in the manner that is disclosed by U.S. Patent No. 4,574,914.

[0037] The forward and rearward ends of muffler casing 32 are closed by a pair of corresponding forward and rearward end caps 31, which end caps are complementary in peripheral shape to that of muffler casing 32. Such configuration allows end caps 31 to be welded or otherwise affixed to muffler casing 32 in a well-known manner to thereby form the sound-attenuating muffler chamber therein. As used herein, the terms "forward" and "rearward" refer to the orientation of a muffler installed on a vehicle such that the longitudinal axis of the muffler is parallel with the longitudinal axis of the vehicle upon which the muffler is installed. It will be understood, however, that the muffler can be installed at a 90° or other angle with respect to the longitudinal axis of the vehicle.

[0038] Generally, end cap 31 of the present invention includes a monolithically formed end wall 35 and a tubular inlet/outlet pipe 36 that extends outwardly from the end wall. End wall 35 includes an inlet/outlet opening that is formed as the inner opening or end of a bore 39 of tubular inlet/outlet pipe 36. Together, bore 39 and the inlet/outlet opening in end wall 35 form an intake port or an exhaust port that is in fluid communication with the muffler chamber within muffler casing 32.

[0039] End wall 35 may include casing mounting structure which extends around the periphery of end cap 35 and is complementary in peripheral shape to that of muffler casing 32. In the illustrated embodiment, the casing mounting structure is a continuous flange 40 that provides a suitable surface for welding the end cap to the muffler casing. One should appreciate, however, that the casing mounting structure is not limited to a continuous flange. For example, the end wall may include a thickened peripheral bead, peripherally spaced tabs, and/or other casing mounting structure to facilitate the mounting of the end cap to the muffler casing. Alternatively, the periphery of the end wall itself may be considered to be the casing mounting structure in the event that the flat surface of the end wall is of sufficient structural integrity and is affixed directly to the muffler casing by welding or other suitable means.

[0040] In the embodiment illustrated in FIG. 4 through FIG. 6, end wall 35 includes a monolithically formed, peripheral stiffening or strengthening, upwardly and inwardly extending cap flange or sloping shoulder 43 that extends substantially around the end wall and defines on the interior of the end cap an outwardly projecting space 42 (FIG. 6). In the illustrated embodiment, in which the end cap height dimension is about 3 inches, and the width dimension is approximately 6 to 8 inches, the height of strengthening flange or shoulder 43 is approximately one-quarter inch to one-half inch, and preferably approximately three-eighths inch to five-eighths inch.

[0041] Peripheral shoulder 43 is a tapered surface that extends between a substantially flat outer wall portion or surface 44 and a flat land portion or surface 45 on opposing ends of end wall 35. As shown in FIG. 4, peripheral shoulder 43 also extends along the periphery of end wall 35 between the opposing stepped land surfaces 45 providing the end wall with a stepped groove 46 therebetween.

[0042] In the illustrated embodiment, strengthening shoulder 43 is an angled end wall portion having an angle of approximately 45°. One should appreciate that the angle may vary and, alternatively, may take the form of different shapes. For example, a

filleted transitioning surface interconnecting flat wall portion 44 and land surfaces 45. The configuration of interior space 42 and peripheral shoulder 43 provides end cap 31 with increased structural integrity. One should appreciate that the strengthening shoulder need not extend completely around the end wall, nor be provided at all, in accordance with the broadest aspect of the present invention. One will also appreciate, however, that such shoulders and/or other strengthening structures may be used to provide the end cap with increased structural integrity or stiffness. The method of the present invention easily allows the formation of such strengthening structures or configurations with little or no additional cost or forming difficulty.

[0043] Tubular member 36 extends outwardly from end wall 35. In particular, tubular member 36 extends from end wall 35 adjacent to and surrounding an opening in the end wall which forms an inlet or outlet opening into the muffler chamber. Tubular member 36 is monolithically formed with end wall 35, as is described in greater detail below.

[0044] Tubular member 36 is generally cylindrical in shape and defines bore 39 therein. Bore 39, together with the opening at the inner end of bore 39 in end wall 35, serves as an inlet port or an exhaust port for the entry and exit of exhaust gases either into or out from the muffler casing.

[0045] Structurally, tubular member 36 also provides an inlet or outlet pipe that facilitates installation of muffler 30 into an exhaust system of an internal combustion engine. Thus, pipe 36 provides a structure by which muffler 30 can be readily attached to the exhaust pipe from the engine and the exhaust discharge tail pipe from the muffler in a well-known manner.

[0046] In the embodiment illustrated in FIG. 4 through FIG. 6, the intersection of end wall 35 and tubular member 36 includes a filleted portion 48 that provides a smooth transition between the end wall 44 and stiffening wall portion 43 and tubular member 36. In one embodiment, the filleted portion has a radii within the range of

approximately one-quarter to three-quarters inch, and preferably of approximately one-half inch. One will appreciate, however, that other suitable dimensions may be used.

[0047] In the embodiment shown in FIG. 4, tubular inlet/outlet pipe 36 is asymmetrically located on end wall 35. In particular, tubular pipe 36 is located to one side of end wall 35. One should appreciate that the actual location of the tubular inlet/outlet pipe with respect to the end wall may vary in accordance with the present invention. Mufflers are conventionally constructed with a variety of intake and outlet pipe configurations including side-in, side-out; side in, center-out; center-in, side-out; and center-in, center-out. The end cap of the present invention is adaptable to all of these configurations. An example of a center-in end cap is shown in FIGS. 7-9. The inlet/outlet pipe is centrally located on the end wall, as is discussed in greater detail below. One should also appreciate that one, two, or more tubular inlet/outlet pipe members also may be formed in the end wall. For example, the end cap may be formed with two tubular pipes in order to form two outlets for exhaust systems having two tail pipes downstream of the muffler.

[0048] The end cap and inlet/outlet pipe of the present invention is monolithically formed from a flat sheet of metal. In particular, end wall 35 and tubular inlet/outlet pipe 36 are formed as one piece from a single blank of metal. Tubular inlet/outlet pipe 36 is drawn from the same blank or sheet of material used to form end wall 35. In one embodiment, tubular inlet/outlet pipe 36 has an outer diameter of approximately two and five-eighths inch and a length of approximately two inches. It will be understood, however, that the actual dimensions may vary in accordance with the engine size and volume of exhaust gases produced.

[0049] Preferably, the end cap is formed of 16 gauge aluminized draw quality steel and/or 16 gauge stainless steel such as ULTRA FORM® 409 stainless steel produced in flat rolled form by AK Steel Corporation of Middletown, Ohio. One should appreciate that the end cap may also be formed of other suitable materials including,

but are not limited to 304 stainless steel, aluminum, titanium, and/or other suitable metals. One should further appreciate that the end cap may be formed from various gauges of stock material. For example, the end cap of the present invention can be formed from 16 gauge material, 14 gauge material, and material of other thicknesses suitable to withstanding the temperatures and pressure of the exhaust gases.

[0050] The method of forming the one-piece muffler end cap in accordance with the present invention can now be described. The end cap of the present invention may be formed by cold working processes, including, but not limited to, rolling, hammering, stamping, punching, drawing and deep drawing. Generally, the end cap is formed from an initial blank that is plastically deformed during one or more operations. For example, an initial sheet or strip blank may be processed by a series of operations including deep drawing, stamping and/or punching by means of punch and die sets on a press in order to shape the blank into intermediate shapes, each step involving considerable plastic deformation of the metal. During subsequent operations, the blank progressively assumes a shape increasingly similar to that of the final end cap, namely, a one-piece end cap having a monolithic inlet/outlet pipe extending from the end cap end wall.

[0051] The end cap is fabricated from the initial blank using a punch press or other suitable tooling means. One will appreciate that progressive tooling, transfer-line tooling systems, and/or other suitable tooling may be utilized in accordance with the present invention. A combination of cold working operations are utilized to fashion the final end cap from the initial blank. In one embodiment, it takes approximately seven fabrication steps to work the initial flat sheet blank into the final end cap and pipe.

[0052] In one embodiment of the method, an initial oval-shaped blank of material is provided. The oval blank may be cut from rolled coil stock or provided as a strip blank. In one embodiment, the oval blank measures approximately 7½ x 13 inches, however, one will appreciate that the actual shape and dimensions of the blank will

vary depending upon the final dimensions of the end cap and pipe. One important factor in determining the initial shape and dimensions of the blank is that all of the material necessary to make the final end cap shape must be present prior to the first draw operation performed on the blank.

[0053] With reference to FIG. 10, an initial oval blank is deep drawn at a first tooling station that includes a first punch 53 and first die 54, which are used to form an approximately 4½ inch diameter first cup 51 in the oval blank, thus providing the blank with a first intermediate shape 52. One should appreciate that the actual dimensions of the first intermediate shape may vary in accordance with the requirements of the muffler end cap of the present invention. One will also appreciate, however, that the dimensions should be carefully selected to form an intermediate part within acceptable draw ratio limits in a known manner in order to progressively reshape the oval blank to the desired final shape and profile of the one-piece end cap and pipe.

[0054] Drawn blank 52 is then transferred, either manually or mechanically, to a second punch 57 and a second die 58 and is again deep drawn to further reduce the diameter of cup 51 to the diameter of cup 56, while also deepening the cup. In particular, a second intermediate shape 55 is formed having an approximately 3 inch deep cup 56, as shown in FIG. 11. Again, the dimensions should be carefully selected to form an intermediate part within acceptable draw ratio limits. The tapered end 62 (FIG. 10) of cup 51 allows the larger diameter cup 51 to rest on arcuate die surface 63 (FIG. 11) so that the diameter reduction can be effected during the second drawing step.

[0055] Next, second intermediate shape 55 is transferred to a third punch 65 and third die 66 (FIG. 12) and the blank is again deep drawn in order to further reduce the diameter of the cup to approximately 2½ inches thus forming a third intermediate shape 59 having a 2½ inch diameter cup 60, as shown in FIG. 12. In this embodiment, cup 60 approximates the final diameter of tubular inlet/outlet pipe 36 of

final end cap 31. In the event that smaller diameter pipes are desired, one or more additional deep drawing operations may be performed. Alternatively, punch and die sets of different dimensions may be used to form the smaller diameter in the same number or fewer number of steps, provided that acceptable draw ratios are used in each step.

[0056] In this embodiment of the method, the blank or third intermediate shape 59 is then transferred to a fourth punch 74 and a fourth die 75 and subjected to a draw operation often referred to a "dimple draw." In this embodiment, a fourth intermediate shape 61 that includes space 42 defined by stiffening or strengthening sloped shoulder 43 is formed. In this embodiment, fourth intermediate shape 61 (FIG. 13) now also includes strengthening shoulder portion 43 defining interior space 42, as well as filleted or flared transition portion 48, but still retains the 2½ inch cup 59 formed during the preceding deep draw operation. One will appreciate that, in the event one or more additional deep draw operations are performed prior to the dimple draw operation, the intermediate shape would retain the corresponding diameter cup of the additional deep draw operations.

[0057] In the next step, the blank or fourth intermediate shape 61 is transferred to a fifth punch 84 and a fifth die 85 and is subjected to a stamping operation in which the outside lip or mounting flange 40 is formed, as shown in FIG. 15. In this embodiment, fifth intermediate shape 64 is formed that retains the shape of cup 59, flange 43 and filleted portion 48, and which now includes mounting flange 40.

[0058] The fifth intermediate shape 64 is then transferred to a sixth punch 94 and a sixth die 95 and subjected to a punching operation in order to transform cup 59 of FIG. 14 into a through-pipe 69 thus almost completing the formation of the inlet or outlet pipe of the end cap. As shown in FIG. 15, a circular disc 67 is punched-out from the bottom of cup 59, thus forming a sixth intermediate shape 68 having an intermediate through-pipe 69. Intermediate through-pipe 69 includes an opening 71

defined by a rounded shoulder 72. Sixth intermediate shape 68 otherwise retains the other features previously formed.

[0059] Lastly, sixth intermediate shape 68 is transferred to a seventh punch 96 and a seventh die 97 and subjected to a drawing operation in which the curved shoulder of the intermediate through-pipe is flared outwardly thus substantially forming the final cylindrical shape of the inlet/outlet pipe of the end cap. As shown in FIG. 16, end cap 31 is monolithically formed with an end wall 35 having a tubular inlet/outlet pipe 36.

[0060] In other embodiments, an end cap may be formed utilizing one, two, or more deep draw operations in combination with one or more other operations in accordance with the present invention. One will appreciate that a wide variety of methods may be utilized to form a monolithic end cap in accordance with the present invention. For example, in the event that an end cap having a 3 inch tubular member without an internal strengthening shoulder 43 is desired, the end cap may be formed in five steps instead of seven. In particular, only five punch and die sets similar to those illustrated in FIGS. 10, 11, 14, 15 and 16 would be necessary, as additional punch and die sets to reduce the diameter to 2½ inches and to form the dimple would not be necessary.

[0061] Advantageously, the method of the present invention eliminates the pipe-forming and the welding steps that are necessary to form conventional end caps found in the prior art.

[0062] The one-piece muffler end cap of the present invention benefits the entire muffler manufacturing process and provides a more durable product. The method of the present invention allows the production of a complete end cap, for example, an end cap 31 having an end wall 35 and a pipe 36, from a coiled sheet of steel without welding and without the need of rolling an intermediate article of manufacture, namely, a rolled and seamed pipe.

[0063] Although the method of the present invention may or may not require a greater number of steps to form an end cap, the process is simplified due to the elimination of the welding and tube forming steps. Such a streamlined process also provides other benefits in material handling.

[0064] Advantageously, the end cap and method of the present invention increase the durability of mufflers incorporating such new and improved end caps approximately six times over standard mufflers which utilize conventional end caps of the prior art having welds and rolled pipes having seams.

[0065] In another embodiment of the present invention, end cap 31a is similar to end cap 31 described above but includes a centrally located inlet/outlet pipe 36a, as shown in FIG. 7 through FIG. 9. Like reference numerals have been used to identify like components of end caps 31 and 31a. In this embodiment, peripheral shoulder 43a extends upwardly from a pair of symmetrically shaped stepped lands 45a. In operation and use, end cap 31a is formed and used in substantially the same manner as 31 discussed above.

[0066] One should appreciate that a muffler utilizing the one-piece end cap of the present invention may include a pair of similarly shaped end caps or a pair of differently shaped end caps to enclose the muffler casing. For example, a muffler may be formed using two end caps 31, each having an asymmetrically located pipe 36. Another muffler may be formed using two end caps 31a, each having a centrally located inlet/outlet pipe 36a. Yet another muffler may be formed using a first end cap 31 having an asymmetrically located pipe 36 and a second end cap 31 a having a centrally located pipe 36a. One should appreciate that other configurations may also be used in accordance with the present invention.

[0067] For convenience in explanation and accurate definition in the appended claims, the terms "up" or "upper", "down" or "lower", "inside" and "outside" are used

to describe features of the present invention with reference to the positions of such features as displayed in the figures.

[0068] In many respects the modifications of the various figures resemble those of preceding modifications and the same reference numerals followed by the subscript "a" designate corresponding parts.

[0069] The foregoing descriptions of specific embodiments of the present invention have been presented for purposes of illustration and description. They are not intended to be exhaustive or to limit the invention to the precise forms disclosed, and obviously many modifications and variations are possible in light of the above teaching. The embodiments were chosen and described in order to best explain the principles of the invention and its practical application, to thereby enable others skilled in the art to best utilize the invention and various embodiments with various modifications as are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the Claims appended hereto and their equivalents.